

Technical Report 659



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# Reverse Engineering: Human Factors, Manpower, Personnel, and Training in the Weapon System Acquisition Process

David M. Promisel, Christine R. Hartel, Jonathan D. Kaplan,  
Arthur Marcus, and John A. Whittenburg

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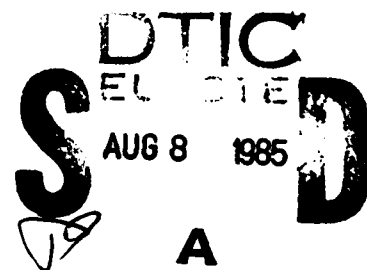


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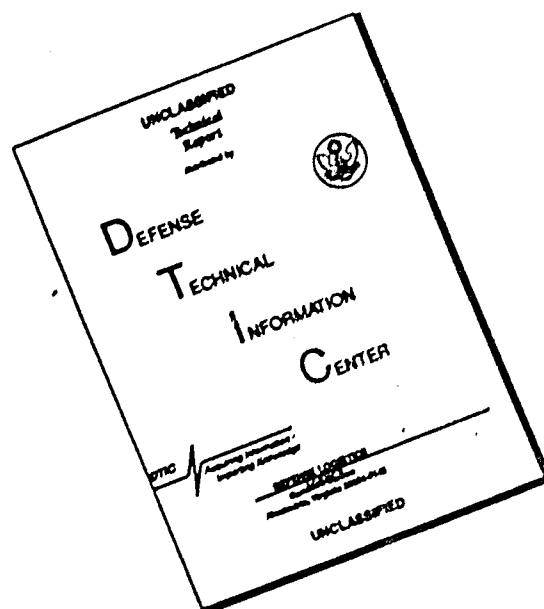
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(HMPT) issues and identify critical events in the weapon system acquisition process (WSAP). If proper attention from an HMPT perspective were given to these critical events, then fielding of operationally useful systems would be facilitated. Approaches for accomplishing this would be developed based on the detailed information acquired from the study of the individual systems.

A study was undertaken based on the "reverse engineering" of four systems: STINGER, Multiple Launch Rocket System (MLRS), BLACK HAWK (UH-60A), and the Fault Detection and Isolation Subsystems of the M1 tank. The term "reverse engineering" is intended to suggest the process of determining how products of the WSAP came to be as they are. This is the final report of the project. It contains a description of the study process, brief summaries of the analysis of the individual systems, the synthesis of the four systems studies, and the recommendations and products that were developed.

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# **Reverse Engineering: Human Factors, Manpower, Personnel, and Training in the Weapon System Acquisition Process**

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## FOREWORD

The Army's weapon system acquisition process has been designed to include human factors, manpower, personnel, and training (HMPT) considerations in a comprehensive and timely fashion. However, this intent has not always been realized. Recently, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has been undertaking a series of special studies in response to a request by General Maxwell Thurman, now Vice Chief of Staff, who has been particularly concerned about HMPT issues in system design. The first study was a "reverse engineering" analysis of the development of four specific systems to identify how and where to influence the acquisition process to result in effective use of soldiers in weapon systems. This is the final report of that study. It presents the synthesis of findings regarding the individual weapon systems into conclusions and general recommendations for the weapon systems acquisition process.

The reverse engineering project is the core from which a number of other studies and products will evolve, all with the objective of obtaining more effective representation of HMPT in systems development. Two such ARI research products have been published to date: HMPT Required Operational Capability (ROC) Enhancement, ARI Research Product No. 84-23; and HMPT Clauses for the Concept Exploration and the Demonstration and Validation Requests for Proposal, ARI Research Product No. 84-24. These are intended to result in system requirements documents that are more comprehensive with regard to HMPT objectives and constraints; system contractual documents that are more informative and explicit in terms of the role HMPT considerations must play in system design.



EDGAR M. JOHNSON  
Technical Director



# REVERSE ENGINEERING: HUMAN FACTORS, MANPOWER, PERSONNEL, AND TRAINING IN THE WEAPON SYSTEM ACQUISITION PROCESS

## EXECUTIVE SUMMARY

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The Army weapon system in the field is the product of a complex acquisition process. The process has been formalized "... to prescribe a sequence of events and phases of program activities and decisions leading to efficient and effective fielding of fully supportable systems responsive to validated Army requirements." The weapon system acquisition process (WSAP) has been designed to include human factors, manpower, personnel, and training (HMPT) considerations in the system design in a comprehensive and timely fashion. However, this intent has not always been realized. Many reasons have been offered for the lack of adequate HMPT considerations including: delay or absence of analysis of HMPT requirements; inadequate information on human limitations; inadequate techniques for predicting manpower and personnel requirements; lack of attention to soldier performance in test and evaluation; and insufficient incentive for project managers, test directors, contractors, etc. to attend properly to HMPT issues in the face of competing priorities. Solutions proposed range from improved HMPT technology to better handbooks on human performance to stiffened regulations and review as part of the formal WSAP.

The objective of the Reverse Engineering Project is to identify how and where to influence the acquisition process to result in effective use of soldiers in weapon systems. The project was initiated at the request of General Maxwell Thurman while he was Deputy Chief of Staff for Personnel. It was his position that careful examination of the development process of several Army weapon systems would provide specific illustrations of HMPT and identify critical events in the WSAP. If proper attention from an HMPT perspective were given to these critical events, then fielding of operationally useful systems would be facilitated. Approaches for accomplishing this would be developed based on the detailed information acquired from the study of the individual systems.

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has been heavily involved in systems manning technology research for some time. ARI responded to GEN Thurman's request by undertaking a study based on the "reverse engineering" of four systems: STINGER, Multiple Launch Rocket System (MLRS), BLACK HAWK (UH-60A), and the Fault Detection and Isolation Subsystem of the M1 tank. The term "reverse engineering" was suggested by GEN Thurman and is intended to imply the process of determining how products of the WSAP came to be as they are.

This is the final report of the project. It contains a description of the study process, brief summaries of the analysis of the individual systems, the synthesis of the four systems studies, and the recommendations that were developed.

The general recommendations resulting from the Reverse Engineering Study are as follows:

- Total system performance in the operational environment should be the focus of the WSAP from initial analyses through testing and decision making.
- Past practices (e.g., involving baseline comparison systems or "standard" procedures) should not be adopted for new, or successor, systems without specific analysis of their applicability.
- Actions and documents in the WSAP should not be approved until their comprehensiveness including attention to HMPT has been verified.
- There should be systematic monitoring of processes specified in requirements documents (e.g., trade-off studies) and planning documents.
- WSAP decision making bearing on HMPT issues should reflect estimates of the cost-effectiveness and cost benefits associated with the available options (with respect, for example, to funding and scheduling of the WSAP).
- Characteristics of the acquisition (competition, degree of multiple proponency, accelerated development, etc.) and their impact on HMPT should be explicitly considered in WSAP planning.
- Actions should be taken to reduce turnover and improve HMPT-related training of appropriate personnel in DARCOM, TRADOC, OTEA, and other agencies.
- In selecting and monitoring contractors, the competence of their staff in terms of HMPT should be assured.
- Responsibility for development of the total system including HMPT should be centralized to the maximum extent possible.

REVERSE ENGINEERING: HUMAN FACTORS, MANPOWER, PERSONNEL, AND TRAINING  
IN THE WEAPON SYSTEM ACQUISITION PROCESS

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## I. INTRODUCTION

### Weapon System Performance

A common perception of current weapon systems was characterized recently by a United States Senator<sup>1</sup> when he referred to "the horror stories that have come out of the Pentagon in recent years - weapons that don't work, 1,000 percent cost overruns, 15-cent tools with \$9,000 price tags..." This sense of the inadequacy of system development is not rare. The Government Accounting Office<sup>2</sup> (GAO) has said, in a milder tone: "The United States' ability to fight a war may be severely hampered because many of the ... systems the Armed Forces must use are suffering from numerous problems." The GAO proceeds to relate these problems to soldier issues: "While these systems may have the capability to perform their missions, it is often of little value because not all the systems can be adequately operated, maintained, or supported."

GEN Kerwin, GEN Blanchard, et al.<sup>3</sup> amplified on the soldier issues: "the U.S. Army has a major man/machine interface problem. ... Increasing weapon complexity, the large number of new systems being developed, insufficient formal school training, a declining manpower pool, disproportionate numbers of CAT III B and CAT IV personnel, recruiting and retention problems, and unit turbulence all will continue to strain the already overburdened personnel, training, and development communities."

Several propositions summarize the views of many concerned with the Army's capability to fight:

- o The Army needs smart soldiers;
- o It will be increasingly difficult over the next decade or two for the Army to acquire and retain smart soldiers;

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<sup>1</sup>Roth, William V., Jr. "We Need Professional Armorers," The Washington Post, Washington, D. C., May 20, 1984

<sup>2</sup>Comptroller General of the United States, Effectiveness of U.S. Forces Can Be Decreased through Improved Weapon System Design, Report PSAD-81-17, January 29, 1981.

<sup>3</sup>Kerwin, Walter, T., G.S. Blanchard, E.M. Atzinger and P.E. Topper, Man/Machine Interface - A Growing Crisis, Army Top Problem Areas Discussion Paper No. 2, AMSAA, August 1980.

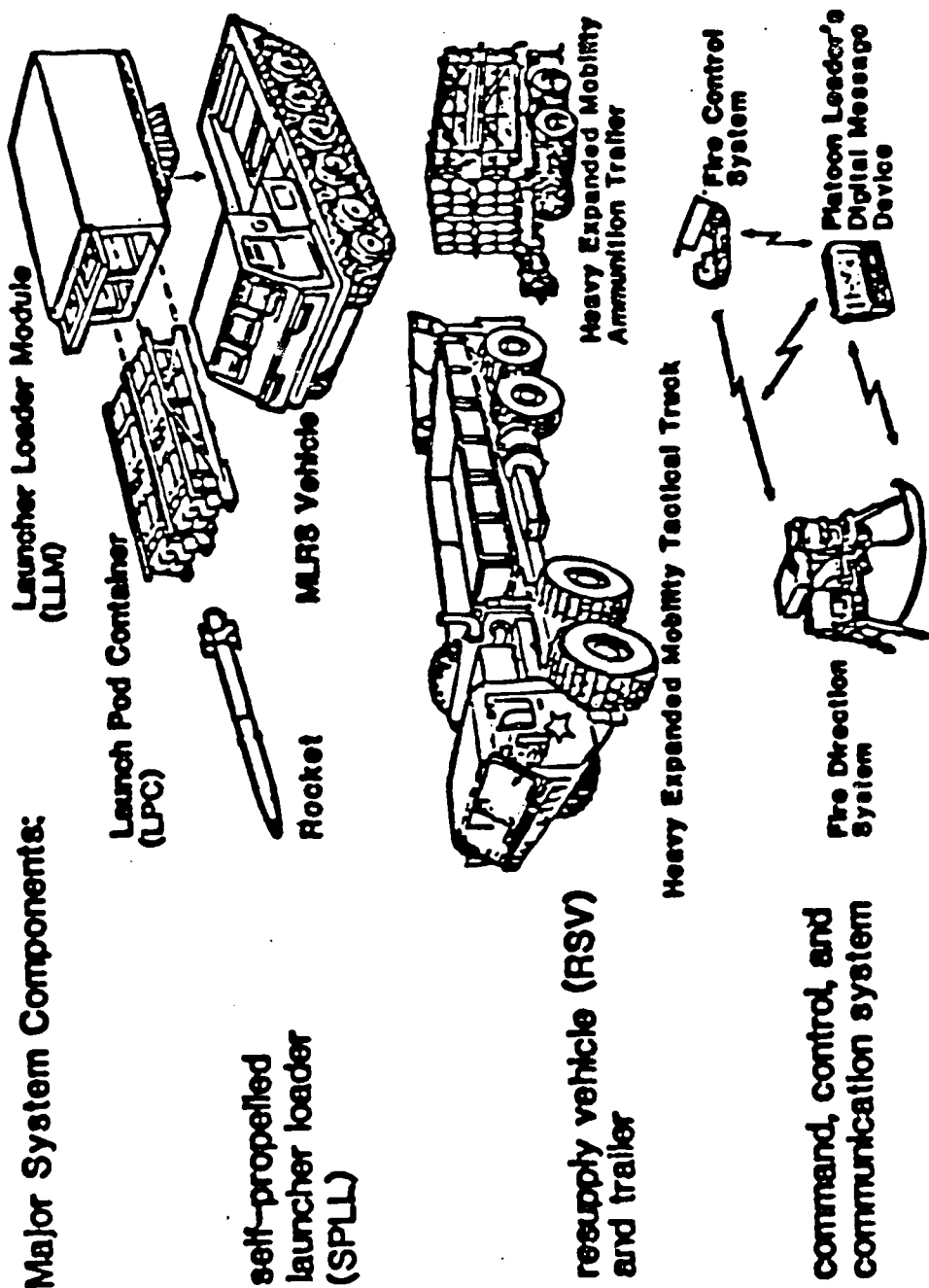


Figure 6. Multiple Launch Rocket System (MLRS) major components.

- o These issues could have been addressed early in the engineering development phase.

### Multiple Launch Rocket System (MLRS)

Mission. The mission of MLRS is to provide general artillery support as well as to complement standard cannon artillery in air defense suppression and counterfire roles, to supplement other general support systems engaging high density mechanized targets during surge periods, and to provide interdiction support against second echelon targets such as troops, light equipment, target acquisition systems, air defense sites, logistics complexes, and command/control centers.

Description. The MLRS is composed of the following major components (see Figure 6): 1) all weather, fully tracked self-propelled launcher loader (SPLL), made up of two launch pod containers (LP/C) with six rockets each, a launcher loader module (LLM) capable of housing the LP/Cs, and a carrier vehicle; 2) heavy expanded mobility tactical truck (HEMTT) and heavy expanded mobility ammunition trailer (HEMAT) for use as resupply vehicles (RSV); and , 3) a command, control and communication system (C<sup>3</sup>). The fire control system (FCS) is located on board the SPLL; the fire direction system (FDS) is located at the battery level. The platoon leader's digital message device (PLDMD) is the third major C<sup>3</sup> component. The basic unit of the system is the MLRS battery, which is largely autonomous. It is combined with other units to create a variety of organizational configurations. An MLRS battery contains three firing platoons each containing three firing section, i.e., a total of nine SPLL's. Other key battery elements include the fire direction section, survey section, and ammunition platoon.

Operation of a battery is a complex matter involving many functions, much movement, and large geographic areas. The current concept of MLRS operations is characterized by:

- each of the firing platoons occupying an area approximately 1.5 X 2.0 kilometers
- use of several hide areas, firing areas, and reload areas by each SPLL
- precise positioning information required for each SPLL with monitoring by the platoon leader
- fire mission assignments made by the fire direction center directly to the SPLL
- fire control calculations performed by computer in each SPLL

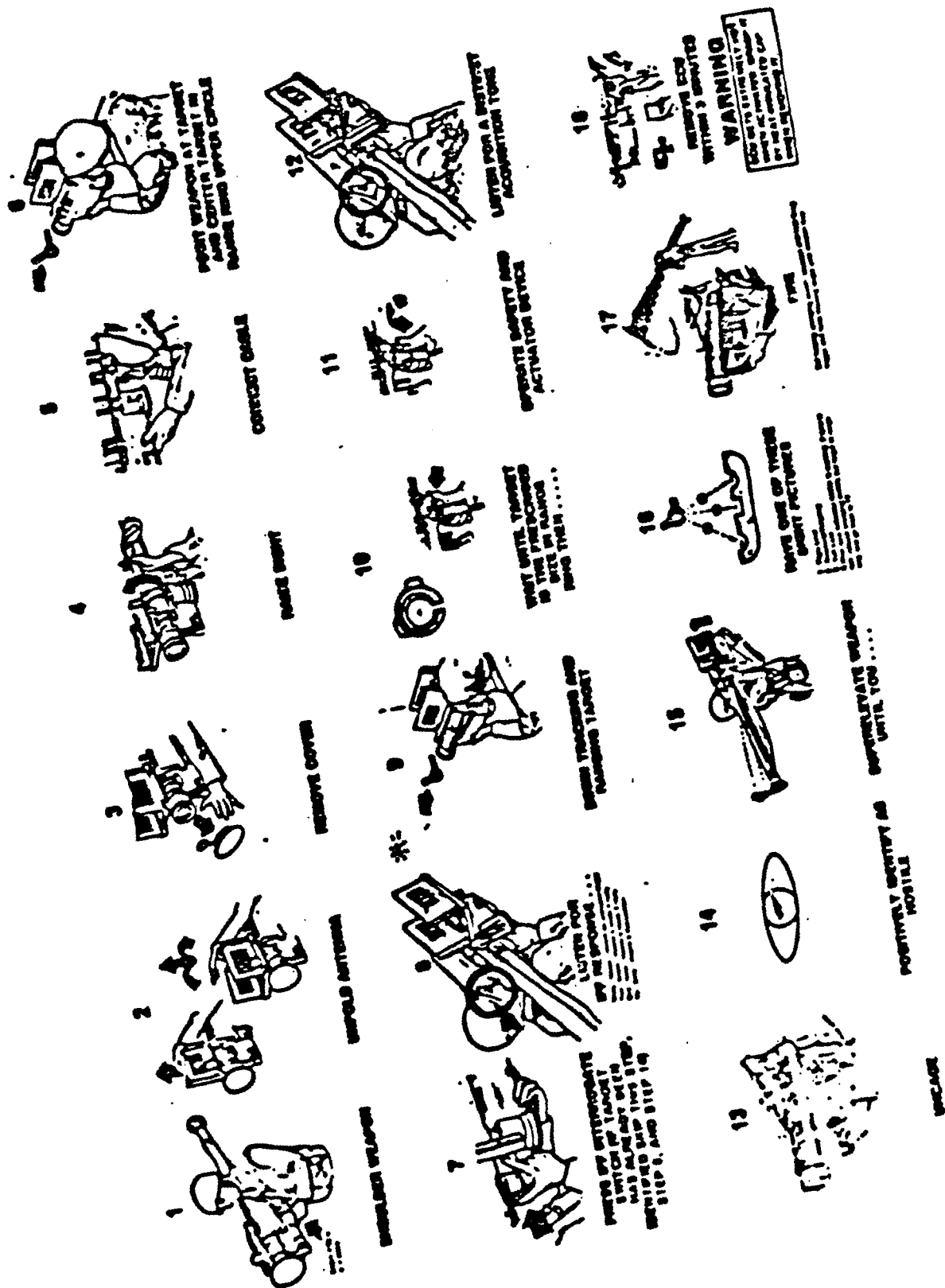


Figure 5. STINGER engagement.



incorporates an Identification Friend or Foe (IFF) system for positive identification of friendly aircraft. -STINGER is operated by a single individual but deployed in teams of two people, a crew chief and a gunner, each of whom are supplied with the weapon. It is capable of being carried by one person although it is generally transported in vehicles.

Acquisition History. A Qualitative Materiel Development Objective for REDEYE II was initiated in January 1970. The equivalent of what are now referred to as the Concept Exploration and Demonstration and Validation Phases were conducted simultaneously from 1970 to 1972. During this period, two joint Army-Marine tests were conducted to assess the gunner's capability to engage targets in the forward hemisphere and to identify targets. It was concluded that forward aspect engagement was feasible but that aids for aircraft identification were needed.

The STINGER Materiel Need Statement was approved in 1972 and an engineering development contract awarded a few months later. Development and operational tests (DT and OT) were conducted in 1977 and production and deployment was authorized in 1978. The STINGER POST system which emphasizes improved aircraft discrimination from electronic countermeasures and noise is currently under development.

HMPT Issues. The tasks for the gunner in implementing a STINGER engagement are many and complex as shown in Figure 5. The reverse engineering analysis determined aircraft identification, ranging, and weapon superelevation as being especially or unnecessarily difficult. STINGER doctrine also imposes burdens on teams and individual gunners in terms of: engaging multiple aircraft approaching a single sector; responding when members of two-man teams are separated; lifting, moving, emplacing and displacing the weapon under varying terrain configurations and visibility; and tactics and mission planning.

#### Major Conclusions.

- o STINGER system requirements were not fully specified, e.g., man-portability was never defined.
- o Analyses conducted to optimize the burden on the gunner did not encompass all required functions.
- o The lower mental category soldiers constituting a large portion of the current population of gunners cannot operate STINGER to meet the required single engagement kill probability.
- o The weapon design could be modified to accommodate better the capabilities of gunners assigned to use it.

### III. Studies of Individual Systems

This section describes briefly the four systems used as case studies in the reverse engineering project and presents some of the results of their analysis. The intent is to provide a background for subsequent discussion of the synthesis of findings from the systems. More detailed accounts of the individual system analyses have been published separately.<sup>5</sup> It should be remembered that it is not the purpose of the study to criticize the individual systems or any of the specific people or agencies responsible for their development. Instead, it is hoped that this effort will help focus the Army's attention on general improvements that can be made in the weapons system acquisition process.

#### STINGER

Mission. STINGER is a man-portable air defense missile system. It is intended for use by air defense personnel in air defense units in implementing both attrition and self defense missions. Its targets are both fixed and rotary wing aircraft appearing at low altitudes and short ranges and at all aspects.

Description. STINGER was conceived as an improvement to the REDEYE system (it was originally called the REDEYE II). Its principle hardware differences from REDEYE consist of an improved infrared guidance system, airframe, and propulsion capability that permit target engagement regardless of flight direction. It also has greater resistance to countermeasures and

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<sup>5</sup>Hartel, C.R. and Kaplan, J.D. Reverse Engineering of the BLACK HAWK (UH-60A) Helicopter: Human Factors, Manpower, Personnel, and Training in the Weapons System Acquisition Process. Alexandria, Virginia: U.S. Army Research Institute, Research Note 84-100, 1984.

Arabian, J.M., Hartel, C.R., Kaplan, Jr.D., Marcus, A. and Promisel, D.M. Reverse Engineering of the Multiple Launch Rocket System: Human Factors, Manpower, Personnel, and Training in the Weapons System Acquisition Process. Alexandria, Virginia: U.S. Army Research Institute, Research Note 84-102, 1984.

Daws, R.N., Keesee, R.L., Marcus, A., Hartel, C.R. and Arabian, J.M. Reverse Engineering of the STINGER Air Defense Missile System: Human Factors, Manpower, Personnel, and Training in the Weapons System Acquisition Process. Alexandria, Virginia: U.S. Army Research Institute, Research Note 84-103, 1984.

Marcus, A. and Kaplan, J.D. Reverse Engineering of the M1 Fault Detection and Isolation Subsystem: Human Factors, Manpower, Personnel and Training in the Weapons System Acquisition Process. Alexandria, Virginia: U.S. Army Research Institute, Research Note 84-101, 1984.

# System Development Process

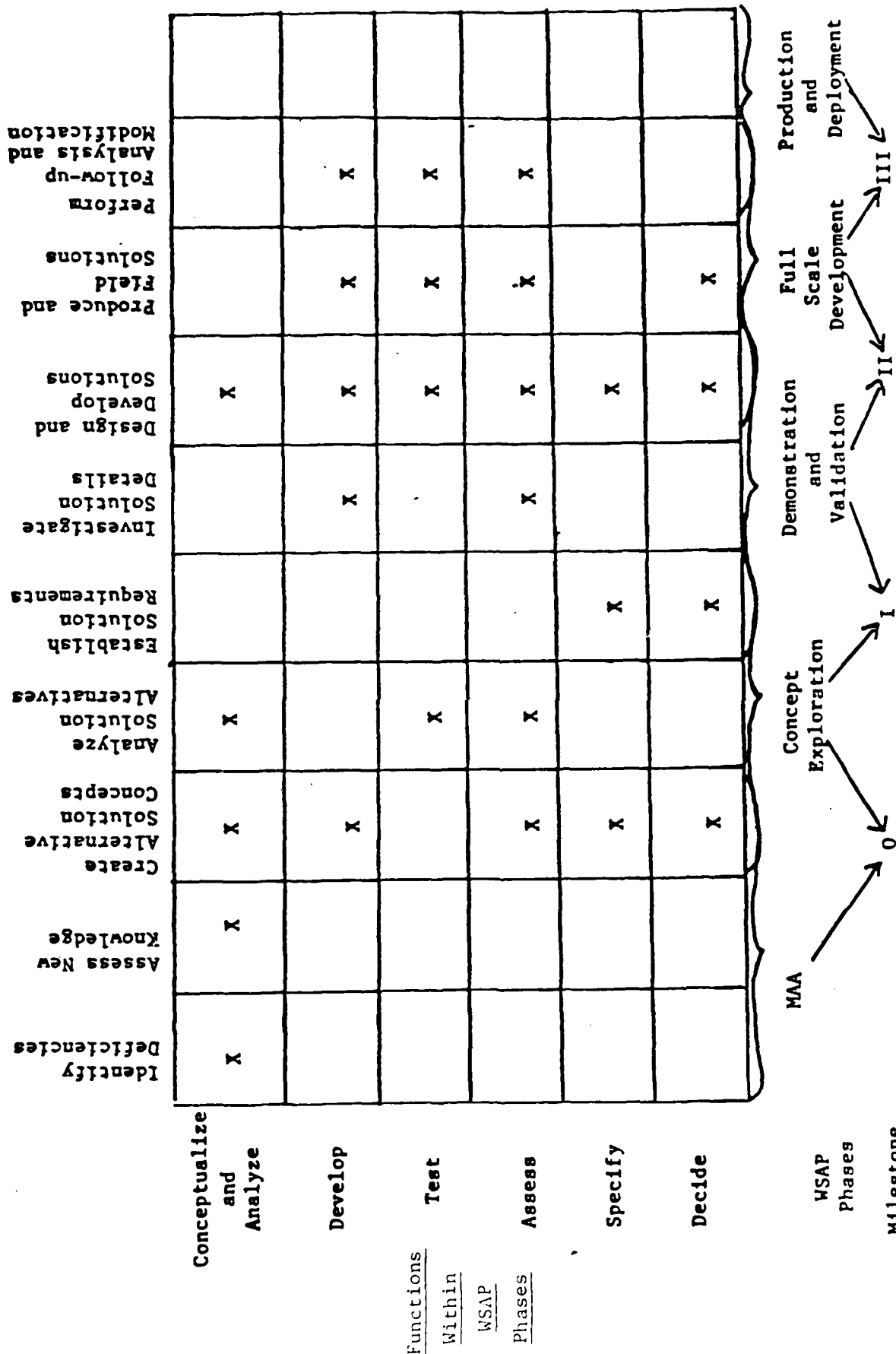


Figure 4. System development process.

**MAJOR MILESTONES** - a point in time at which a recommendation is made and approval sought from higher authority regarding initiation/continuation of a program. The normal milestones are the Program Initiation decision, the Demonstration/Validation decision (Milestone I), Full-Scale Development decision (Milestone II) and Production/Deployment decision (Milestone III).

**MISSION AREA ANALYSIS (MAA)** - an assessment of the capability of a force to perform within a particular battlefield or functional area. The analysis is designed to discover deficiencies in doctrine, organizations, training, and materiel and to identify means of correcting these deficiencies; stressing first doctrinal solutions, then training solutions, then organizational solutions, and lastly, materiel solutions. MAA also provides a basis for applying advanced technology to future Army operations.

**CONCEPT EXPLORATION PHASE** - the initial phase of the materiel acquisition process. During this phase, the Acquisition Strategy is developed, system alternatives are proposed and examined, and the materiel requirements document is refined to support subsequent phases.

**DEMONSTRATION AND VALIDATION PHASE** - normally the second phase in the acquisition process. This phase consists of those steps necessary to resolve or minimize logistics problems identified during Concept Exploration, verify preliminary design and engineering, accomplish necessary planning, fully analyze trade-off proposals, and prepare contract required for full-scale development.

**FULL-SCALE DEVELOPMENT (FSD) PHASE** - normally, the third phase in the materiel acquisition process during which a system, including all items necessary for its support, is fully developed, engineered, fabricated, tested, and initially type classified.

**PRODUCTION AND DEPLOYMENT PHASE** - normally, the fourth phase of the materiel acquisition process. During this phase, operational units are trained, equipment is procured to meet the AAO, distributed, and logistic support is provided.

Figure 3. Definition of terms--the materiel acquisition process (Source: Materiel Acquisition Handbook, DARCOM and TRADOC, 1984, Pamphlet 70-2).

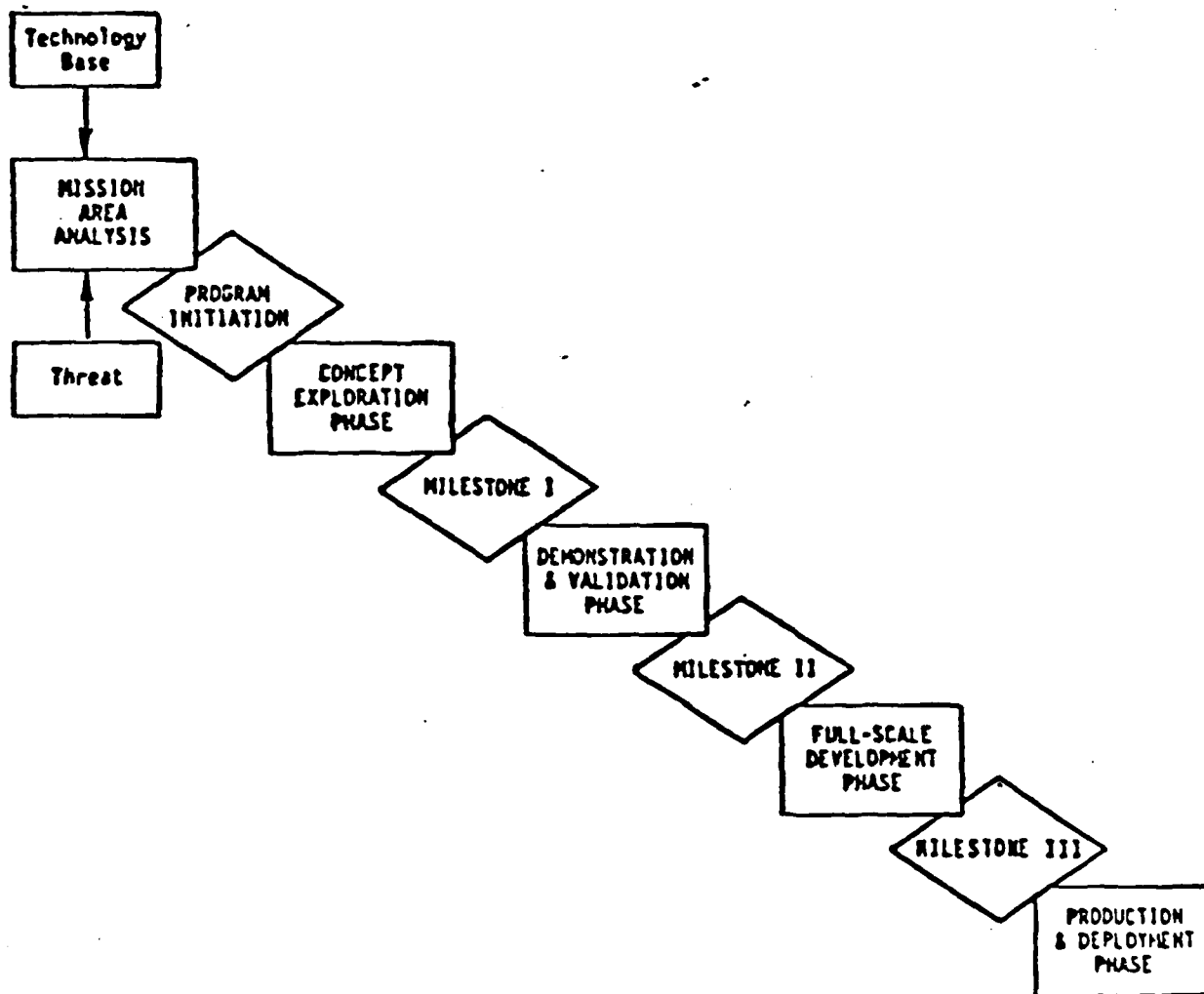


Figure 2. The materiel acquisition process (Source: Materiel Acquisition Handbook, DARCOM and TRADOC, 1984, Pamphlet 70-2).

procedures could easily be added to form a D HMPT categorization. However, for reasons of simplicity and continuity with prior work this study retains the HMPT groupings. Assessment of the design of doctrine and procedures from a soldier perspective is encompassed by the heading of human factors; so is hardware and software design.

Soldier performance issues commonly have multi-dimensional origins. Where performance is inadequate, for example, it may well be the result of hardware design that is unsuitable for the typical capabilities of the crew assigned to the task with the kind of training that was provided. Alleviation of the performance problem may require attention to some combination of HMPT simultaneously. Although soldier performance problems are sometimes described in unidimensional terms in this report, it should be noted that there is almost always a multidimensional consideration.

#### The Weapon System Acquisition Process (WSAP)

The process of development of any system begins when an existing deficiency, or need, is noted and proceeds by considering alternative solution concepts, specifying firm requirements, developing and testing designs, producing and putting into use an operational system, and monitoring its subsequent effectiveness. For purposes of the Weapon System Acquisition Process, the LCSMM codifies system development activities into a series of phases of activity bounded by milestones, or decision points. Figure 2, adopted from the Materiel Acquisition Handbook, illustrates this concept. Definitions of terms in the model are contained in Figure 3. Rarely does a procurement follow the model exactly; however, the model does serve as a convenient baseline for analysis.

Each phase of the process consists of a series of activities that can be referred to as: conceptualize and analyze, develop, test, assess, specify, and decide. As the WSAP proceeds emphasis changes from conceptualization to development and evaluation, options are reduced, the level of detail increased, etc. It has proven useful to categorize, in this way, the events and documents of the formal WSAP for purposes of analysis.

The relationships among these various ways of describing system development is shown in Figure 4. The LCSMM phases can be mapped into the system development functions with some degree of overlap. While all generic activities appear in each phase they do not relate to each system development function. These concepts have been used to aid in the synthesis of findings from the four system studies.

Table 1

HMPT Parameters

Human Factors

- o task allocation
- o man/machine interface
- o health and safety

Manpower

- o soldier supply and cost
- o career structure, rotation policy, etc.

Personnel

- o required capabilities
- o selectability
- o availability

Training

- o individual/collective
- o unit/institutional
- o initial/refresher
- o entry/advanced level

- o problem areas in system performance were identified
- o HMPT factors were examined for their impact on the problematic aspects of system performance
- o the WSAP for each system was reviewed to identify features that contributed to HMPT issues

The findings from the four systems studies were synthesized to arrive at conclusions regarding generic problems in the WSAP related to HMPT. Recommendations were developed for methods to improve the process from an HMPT perspective.

Information sources for ARI's study include:

- DARCOM Project Managers Offices
- DARCOM Weapon Systems Managers
- TRADOC System Managers
- TRADOC Schools and Boards
- Operational Test and Evaluation Agency
- Army Materiel Systems Analysis Activity
- Soldier Support Center
- Weapon System Contractors
- Human Engineering Laboratory
- Sample Data Collection Data Base
- MILPERCEN Data Base
- Special Study Group Reports
- Requirements Documents
- Contractual Documents
- Test Reports
- Independent Evaluation Reports
- Project Management Documents
- Field and Technical Manuals

### Soldier Issues

There are many parameters that can be used to define the relationship of the soldier to the weapon system. One frequent categorization and the one used in this study refers to human factors, manpower, personnel and training (HMPT). Some of the parameters subsumed under these categories are shown in Table 1. It should be clear that the items listed neither completely describe soldier issues nor can they be considered independently of one another in the system design process.

For example, doctrine and procedures are defined for every system and play a major role in soldier functioning. In some instances their development could determine the adequacy or inadequacy of soldier performance with a fixed configuration of hardware and software. Thus, doctrine and



- STINGER
- Multiple Launch Rocket System
- BLACK HAWK
- M1 Fault Detection and Isolation Subsystem

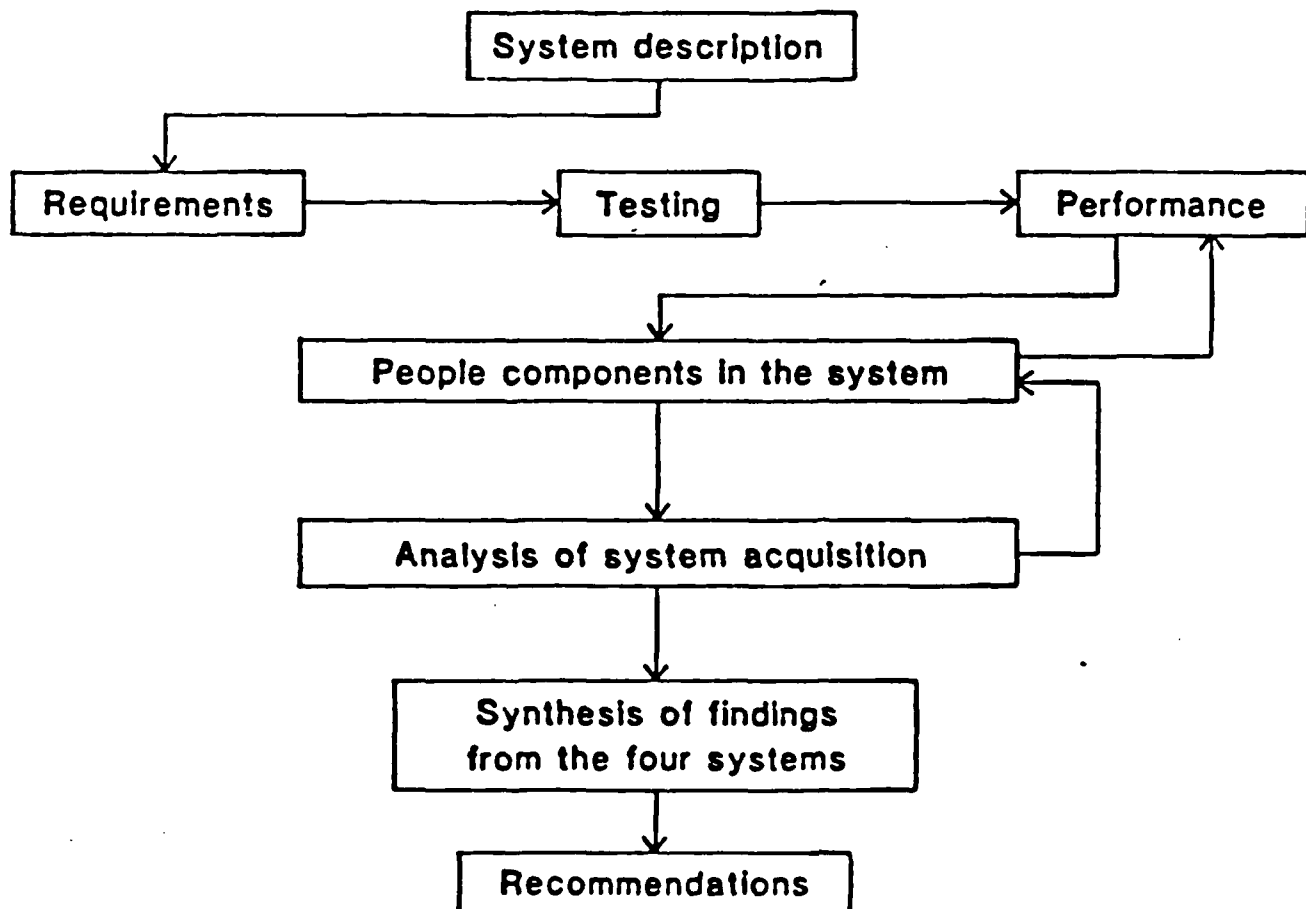


Figure 1. General approach--reverse engineering.

operationally useful systems would be facilitated. Approaches for accomplishing this would be developed based on the detailed information acquired from the study of the individual systems.

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## II. The Reverse Engineering Process

### Premises

A basic premise underlying the reverse engineering study is that analysis of the relationship between HMPT problems and the WSAP should be guided by critical features of the product of the WSAP, i.e., the performance of the system. The significance attributed to HMPT issues should be related to their impact on system effectiveness. Additional premises include the notion that soldier issues should be disaggregated into components of human factors, manpower, personnel, and training and that the Army's formal Life Cycle System Management Model (LCSMM) should be used as the basis for analysis of the WSAP. These will be discussed further, later in this section.

### Approach

The design of the Reverse Engineering study is illustrated in Figure 1. Four systems were studied and the same general approach was followed in each of them:

- o the system was defined and described
- o requirements documents were reviewed to determine how system performance was specified
- o test and evaluation data were analyzed and compared to performance criteria

- o The Army is not developing weapon systems that work well when they get into the field;
- o A major contributor to this lack of systems capability is the Army's inability to use effectively the soldiers available to operate and maintain weapon systems equipment;
- o These problems are going to worsen because weapons are becoming more complex while the supply of capable soldiers is decreasing.

In other words, the Army must improve its weapon system performance by making better use of fewer and less capable soldiers.

#### Materiel Acquisition

The Army weapon system in the field is the product of a complex acquisition process. The process has been formalized "... to prescribe a sequence of events and phases of program activities and decisions leading to efficient and effective fielding of fully supportable systems responsive to validated Army requirements."<sup>4</sup> The weapon system acquisition process (WSAP) has been designed to include human factors, manpower, personnel and training (HMPT) considerations in the system design in a comprehensive and timely fashion. However, this intent has not always been realized. Many reasons have been offered for the lack of adequate HMPT considerations including: delay or absence of analysis of HMPT requirements; inadequate information on human limitations; inadequate techniques for predicting manpower and personnel requirements; lack of attention to soldier performance in test and evaluation; and insufficient incentive for project managers, test directors, contractors, etc. to attend properly to HMPT issues in the face of competing priorities. Solutions proposed range from improved HMPT technology to better handbooks on human performance to stiffened regulations and review as part of the formal WSAP.

#### Reverse Engineering

The objective of the Reverse Engineering Project is to identify how and where to influence the acquisition process to result in effective use of soldiers in weapon systems. The project was initiated at the request of General Maxwell Thurman while he was Deputy Chief of Staff for Personnel. It was his position that careful examination of the development process of several Army weapon systems would provide specific illustrations of HMPT issues and identify critical events in the WSAP. If proper attention from an HMPT perspective were given to these critical events, then fielding of

<sup>4</sup>U.S. Army DARCOM and TRADOC, Headquarters. Materiel Acquisition Handbook, DARCOM and TRADOC, 1984. Pamphlet 70-2, January 20, 1984.

- rapid SPLL movement to firing area and from firing area to leave vulnerability zone, i.e., "shoot & scoot."
- extensive use of resupply vehicles to keep resupply points stocked with rockets

Acquisition history. The MLRS acquisition process was both accelerated and competitive. Four contractors participated in the Concept Exploration Phase. Following ASARC/DSARC I, in January 1977, two contractors, Boeing and Vought, were selected for the 29-month Competitive Validation Phase. Demonstration and Validation and Full Scale Development Phases were eliminated, as was Milestone II. In July 1979, the MLRS was established as an international program. OT I was held at the end of the Competitive Validation Phase. Two months later, ASARC/DSARC III was held and the 31-month Initial Production/Maturation Phase commenced with Vought as the selected contractor. DT/OT III was conducted from October 1982 to January 1983 and the Initial Operating Capability was achieved in March 1983. There was also a General Officer Review in March 1983 where certain deficiencies were noted and full-scale production was authorized. A Follow-on Evaluation was scheduled for the summer of 1984 to assess progress in correcting the deficiencies.

HMPT Issues. The MLRS battery must perform a number of functions to fulfill its missions. However, MLRS requirement documents refer to a series of system "characteristics" rather than functions. There is not a one-to-one relationship between the two methods of description. This is illustrated in Figure 7. The characteristics reviewed were selected because of their importance to MLRS operations and the potential impact HMPT may have on them.

Specific examples of HMPT issues include:

- o Direct support (DS) maintenance met MTTR criteria during OT III. Nevertheless, key battery personnel focused criticism on DS maintenance personnel citing lack of experience and poor collective training as possible problems. These difficulties may be attributable to (1) the decision to create a new MOS 27XX (system repairer) for DS maintenance that was not made until mid-1981 and (2) the decision that was not made until early 1983 to develop a DS maintenance training device. It is scheduled for delivery by March 1985.
- o The MLRS Required Operational Capability (ROC) describes several training devices all of which pertain to operation (not including maintenance) of the SPLL. The preponderance of training shortfalls identified refer to performance (e.g., SPLL maintenance, battery or platoon C<sup>3</sup>, land navigation for resupply vehicles) not directly related to use of the SPLL.

# CHARACTERISTICS

FUNCTIONS	CHARACTERISTICS				
	System Accuracy	System Reaction Time	Command, Control & Communications	Ammunition Resupply	Reliability, Availability & Maintainability (RAM)
Detonate submunitions on target			X		X
Launch rockets	X	X	X	X	X
Place SPL in position to engage targets	X	X	X		X
Assign targets to SPL	X	X	X		X
Keep SPL supplied with rockets		X	X	X	X
Protect SPL when not engaging targets		X	X		X
Maintain SPL availability to engage targets		X	X		X

Figure 7. System characteristics selected for review and their relation to system functions.

- o SPLP crew members (MOS 13M and 15D) have scored higher on the AFQT than other new Army accessions in each of the last three years (1981, 1982, 1983). There has been no formal attempt to test the sensitivity of SPLP performance to the quality of personnel. That is, we do not know what would happen if the calibre of the crew should drop.

#### Major Conclusions.

- o A comprehensive system description for MLRS encompassing the complete mission and all system functions and components was not developed.
- o Requirements and system assessment were addressed in terms of machine, not man-machine, system performance
- o As a result it is not clear what total system performance should be expected of MLRS
- o Nevertheless, there are HMPT problems that clearly affect system performance
- o Most of these problems could have been forestalled if there had been a clearer concept of the system

#### BLACK HAWK (UH-60A)

Mission. The BLACK HAWK supports the Army's airmobility doctrine for employment of land forces in the 1980's. Its mission is to transport air assault troops, provide short range combat support, provide combat service support (equipment and troop movement), carry the air cavalry and provide aeromedical evacuation.

Description. The BLACK HAWK (originally known as the Utility Tactical Transport Aircraft System) is a twin-engine, single-rotor helicopter. It was designed to be the Army's first true squad-carrying helicopter, capable of transporting up to 14 combat-equipped troops and a crew of three or an internal load of 2640 lbs. at 4,000 feet pressure altitude and 95° F ambient temperature. Externally, it can carry up to 8,000 lbs. so that, for example, it can carry a 105mm howitzer and its crew. Typically, 15 BLACK HAWK'S are fielded in a Combat Support Aviation Company. The BLACK HAWK was intended to replace the UH-1, Huey. It is faster, carries a larger payload, and is more crashworthy and survivable.

Acquisition History. The BLACK HAWK acquisition process took 14 years (1965-1979) from the issuance of the first requirements document to Initial Operational Capability. The Engineering Development phase for the airframe was competitive. Sikorsky was awarded the subsequent contract, partly because of its superior performance during Government Competitive Tests, which were part of DT/OT II in 1976. There was no DT III or OT III but a Force Development Test and Experimentation (FDTE) was carried out in mid-1979 to resolve issues raised in OT II. A Required Operation Capability (ROC) for the BLACK HAWK Improvement Program was submitted for review in May 1982. It calls for improvement to "correct current operational deficiencies and align the aircraft capability with the Air Land Battle 2000 Concept."

HMPT Issues. Based on a review of system requirements, test and evaluation and soldier performance, the reverse engineering analysis focused on the topics of reliability, availability and maintainability (RAM), safety, and mission planning. For example:

- o Assessment of RAM performance and scoring criteria used during RAM testing permitted exclusion of soldier-produced failures from consideration. The results, as illustrated in Table 2, were unrealistically high estimates of system (i.e., man-machine) performance.
- o Overall, human engineering and safety considerations were effectively included in the system design. However, the U.S. Army Safety Center reported in 1984 that half the BLACK HAWK accidents to date had been due to human errors, the single largest factor being crew error during night flight. There was a failure to define operationally the requirements for missions including nap-of-the-earth (NOE) and night flying. This led, in part, to incomplete testing from the HMPT viewpoint.
  - The criterion speed for NOE testing was at an unrealistic altitude (300 ft); therefore, there was no way to determine whether the speeds achieved at lower altitudes were satisfactory.
  - Test aircraft were not instrumented, so handling, maneuvering and navigation could not be measured during OT II
  - As a result adequate safety guidelines were not developed for NOE or night flying missions in BLACK HAWK
- o The implications of mission planning are not confined to safety issues. Mission planning also bears on hardware necessary to modify the aircraft for performance of different missions, and

TABLE 2

BLACK HAWKReliability Performance

	Criteria (MN)	Test Results (FDTE)	
System Mean Time Between Failures (Hours)	4.0		
Human Errors Excluded		3.32	30%
Human Errors Included		2.32	Decrease
System Mean Time Between Mission Aborts (Hours)	75.0		
Human Errors Excluded		29.68	40%
Human Errors Included		17.65	Decrease



full utilization of the capabilities of the helicopter. To illustrate, concurrent acquisition of flight simulators, maintenance trainers, and mission flexibility kits necessary for operational performance of the entire weapon system was not carried out and many items were still not available in the Spring, 1984. Consequences include poorer training, increased cost and impaired mission capability.

#### Major Conclusions.

- o The BLACK HAWK met its hardware performance specifications in the areas of human factors/safety and RAM, if human-caused failures are omitted from the evaluation.
- o Failure to define fully mission requirements, e.g., those requiring nap-of-the-earth or night flying, make it impossible to evaluate completely system performance.
- o Delays in the acquisition of Mission Flexibility Kits, Peculiar Ground Support Equipment, Test Measurement and Diagnostic Equipment, and flight and maintenance simulators have cost time, money and effort in compensating for the delays.
- o These findings all illustrate a concentration on hardware acquisition that makes it difficult to evaluate the performance of the man-machine system that is BLACK HAWK.

#### M1 Fault Detection and Isolation Subsystem

Mission. The Materiel Need Statement for the M1 tank included the following requirements as part of its logistical concept:

- o 90% of all malfunctions detectable and correctable at operational/organizational level
- o built-in test equipment (BITE) to be incorporated in design wherever practicable
- o design to require least amount of specialized support and test equipment
- o MS+ concept of modular replacement (with a "fix forward, repair to the rear" emphasis)
- o tank design to incorporate ease of maintenance

For purposes of reverse engineering, the test and diagnostic procedures, equipment, and personnel that have evolved to meet these requirements constitute the "fault detection and isolation subsystem."

Description. The elements of the subsystem include BITE; test, measurement and diagnostic equipment (TMDE); technical manuals; and trouble-shooting procedures. There are two types of BITE on the M1: automotive (visual status indicators) and fire control system (manually initiated built-in test sequence). The TMDE includes three types of automatic test equipment (ATE) that must be attached to the tank when malfunctions occur. These are the Simplified Test Equipment Test Set (STE/M1), Direct Support Electrical System Test Set (DSESTS) and the Thermal System Test Set (TSTS).

Acquisition History. The Main Battle Tank Task Force was established in 1972 to define requirements for a new tank. After an accelerated conceptual phase competitive, 34-month advanced development contracts were awarded to General Motors and Chrysler in 1973.

A major factor in the M1 acquisition cycle which directly influenced development of the fault-detection and isolation capability was postponement of the Integrated Logistics Support (ILS) package until full scale engineering development which began late in 1976. Tank hardware considerations were the driving force in the M1 development; a systematic effort was not made to develop and integrate requirements for BITE/TMDE hardware with those for maintenance personnel, test procedures or other technical documentation. An ATE office was established by the program manager in 1978 and a Troubleshooting Task Force was formed in 1980.

The acquisition and early operational cycle of the M1 fault detection and diagnostic subsystem can be characterized as turbulent with respect to changes in hardware and the resulting need to modify test set software, technical manuals and training. This turbulence existed as of late 1983 when available information suggested that it remained to some degree with respect to troubleshooting skills, test sets (STE/M1 in particular) technical manuals, and training and training devices.

HMPT Issues. There are examples of soldier problems in each of the human factors, manpower, personnel and training categories ranging from mistrust of the STE/M1 to the everchanging design of training programs. To illustrate:

- o As early as DT/OT II evaluation indicated that the skills, experience and aptitudes provided by the planned TOE and MOS structure were not adequate for maintenance of the M1. Maintainers showed limited understanding of system functions, inability to identify accurately basic faults, and limited facility in using technical manuals.

- o Despite the demands on them, M1 organizational mechanics have been lower in mental category than either all Army soldiers or M1 tank crewmen (see Table 3)
- o There have been a series of perturbations in the M1 training program since OT III. Figure 8 shows the nature of some of these changes and suggests the difficulty of assessing the effectiveness of the training program because of its volatility.

#### Major Conclusions.

- o Early requirements documents neglected maintainer performance.
- o Funding constraints prevented proper ILS effort.
- o Compressed schedule adversely affected HMPT development.
- o This is all symptomatic of the lack of a total systems approach to fault detection and isolation.

#### IV. Sources of HMPT Problems in the Weapon System Acquisition Process

##### Review of HMPT Problems

The brief summaries of the four system studies show that there were HMPT problems with each of them (Table 4) and that their impact persisted at least through the production and deployment phase of the WSAP. The examples discussed on a system-by-system basis can be readily categorized into general problem types (Table 5). At the risk of some redundancy, the problem types will be illustrated from the specific systems.

Human factors engineering (HFE) not addressed for some system components. There were numerous instances of HFE problems of varying importance. These are examples where both HFE was lacking and the consequences may be particularly significant:

- o The functions of the MLRS fire direction center were not integrated into a unified man-machine system.
- o The advantages of an automated STINGER superelevation function were not assessed.
- o The M1 STE is so unwieldy, difficult to transport and difficult to connect to the tank that it actually discourages its use by maintenance personnel

TABLE 3  
DISTRIBUTION OF SOLDIERS  
AMONG MENTAL CATEGORIES

	<u>I-III A</u>	<u>III B - IV</u>
- Army-wide	53%	47%
- MOS 19K (M1 Tank Crewman)	51%	49%
- MOS 45E (Turret Mechanic)	46%	54%
- MOS 63E (Hull Mechanic)	41%	59%

SOURCE: Enlisted Master File  
Date: March, 1984

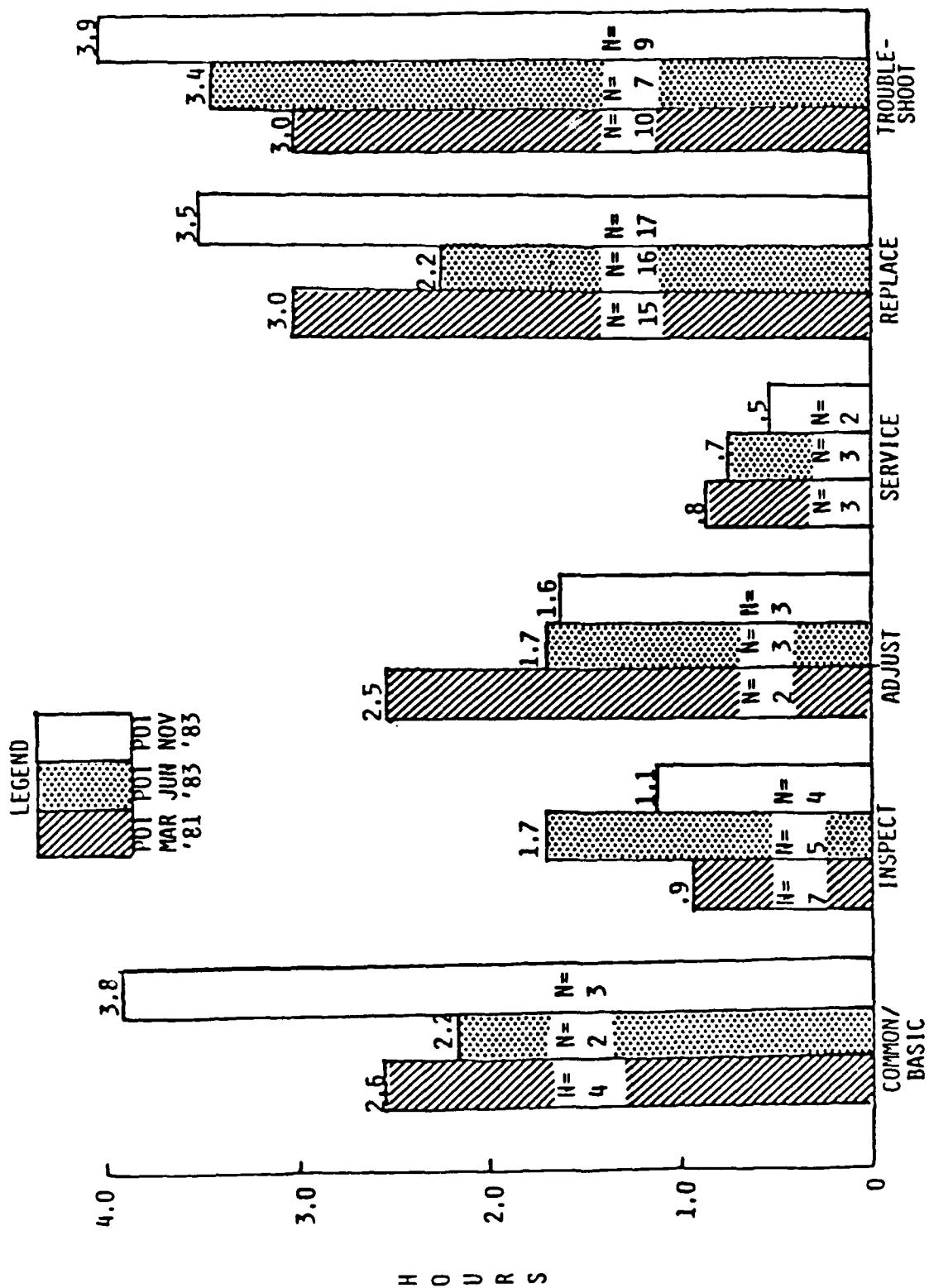


Figure 8. Changes in number of training modules ( $\bar{n} = 1$ ) per maintenance function and average number of hours devoted to each module.

Table 4

Examples of HMPT Problems in the Four Systems Studied

	<u>H</u>	<u>M</u>	<u>P</u>	<u>T</u>
	FDC Positioning Land Navigation	Maintenance Nos. Rank	Maintenance MOS Land Navigation Skills SPLL Ment. Cat.	Maintenance Training Device Communications
	STE Manuals		Troubleshooting Skills DS/GS Ment. Cat	Use of ATE Troubleshooting Training Devices
HAWK	Kits Gunner Position	Maintenance Nos.	Maintenance MOS	Training Devices
BER	Superelevation Ranging O&O		Gunner Selection	Procedures

Table 5

Some Types of HMPT Problems  
Found in the Four Systems

- o Human Factors Engineering not addressed for some system components
- o Doctrine and O&O concepts incomplete or ill-suited to the soldier
- o Manpower levels underestimated
- o Skill and ability needs undetermined or underestimated
- o Training untested
- o Training devices unavailable

Doctrine and operational and organizational (O&O) concepts incomplete or ill-suited to the soldier. These do not fit neatly into an HMPT categorization, as discussed earlier. - However, they are appropriate for HFE analysis since they dictate specific soldier procedures and activities:

- o STINGER O&O defined the concept of two-man teams, but did not treat the one-gunner situation, which could be common; adequacy of performance in this situation was, therefore, not assessed.
- o There was essentially no O&O concept available at the time of MLRS OT I. There has not been an FDTE. The O&O concept remains incomplete and inconclusive regarding demands on the soldier.
- o Soldier implications of doctrine and tactics that fully exploit the BLACK HAWK's capabilities cannot be determined because such doctrine does not yet exist.

Manpower levels underestimated. In the aggregate, some manpower estimates may not appear to be seriously in error (e.g., 6% low for MLRS at the time full-scale production was authorized). However, their consequences may be quite disproportionate for both the system and the total Army:

- o MLRS was authorized three more spaces for its ammunition platoons subsequent to the IOC. This 8.5% increase in manpower results in as much as a 20% increase in the availability of resupply vehicles.
- o There are not enough MLRS direct support maintenance personnel to service the SPLL's because, in part, of the distance that must be traveled between battery units.
- o MOS 67T spaces for BLACK HAWK were underestimated by 21% to 600% at various times; among other consequences it has been necessary to undertake new recruitment initiatives to obtain the numbers required.

Skill and ability needs undetermined or underestimated. One of the Army's primary concern is that new systems may demand too many scarce, highly skilled personnel. However, it is also possible that the Army may underutilize the personnel it does have through inefficient choice of assignments for them:

- o MLRS SPLL crew are above average in terms of mental category. There are no data indicating the necessity for this or what the consequences would be if skills were lowered.



- o Performance with STINGER is correlated with mental category. Other traits may also be correlated but no attempt has been made to identify them.
- o BLACK HAWK requirements documents specified that maintenance should be suitable for personnel with skills equivalent to UH-1 personnel. However, UH-1 personnel skills were not defined operationally and then related to those required by BLACK HAWK.
- o The M1 requires complex troubleshooting skills, yet individuals with the MOS's selected as organizational mechanics are lower in mental aptitude than either M1 tank crewmen or the general population of soldiers Army-wide.

Training untested. Delayed development of training programs leads to the initial fielding of systems with inadequately skilled personnel. Perhaps of greater consequence, however, is that late development of training results in the lack of opportunity to test the operational effectiveness of training:

- o M1 maintenance training programs were still under development in 1984 and would be implemented without formal evaluation.
- o There is a need for improved training for a variety of MLRS tasks. While there may be some sort of process evaluation of this training if it is developed, it is unlikely that there will be a formal evaluation under field conditions.

Training Devices Unavailable. A consequence of the delayed development of training programs can be the lack of training devices to support the fielding of new systems. This can be costly in terms of added training time, diversion of equipment from operational use to support training, or less than adequate soldier performance:

- o The MLRS direct support maintenance training device will not be available until 1985.
- o BLACK HAWK flight simulators will not begin to become available until 1986; some maintenance trainers will not be available until April, 1985.
- o M1 maintenance training devices began to become available only in late 1983.

#### Direct Causes of HMPT Problems

The objective of the reverse engineering study is to use a detailed examination of the development of several systems as a basis for identifying points in the WSAP where actions could be taken to alleviate problems in the

future. The system studies have confirmed the obvious: HMPT problems are readily found in weapon systems. The next task is to identify the factors contributing to the problems, first in direct terms and then in a more general sense.

Examination and synthesis of the circumstances surrounding the specific HMPT problems produces a list of items directly involved in producing them (Table 6). These will be described briefly:

- o mission requirements - ambiguity in describing required system objectives e.g., portability and attrition vs self-defense for STINGER; battery rate of fire for some extended time period for MLRS --makes reasoned system design or trade-off analyses impossible to do properly.
- o system description - incomplete description, such as paying scant attention to MLRS battery functions outside the SPL, produces suboptimized system components, delays in fielding combat-ready systems, etc.
- o system performance measures and standards - gaps in mission requirements and system description, and concentration on hardware rather than system (man and machine) performance are some of the reasons that system performance measures and standards are not developed; where they are developed they are frequently not measurable. Gaps in measures and standards make the adequacy of system design untestable.
- o human performance measures and standards - the problems here are an extension of those associated with system performance. In addition, there is a tendency to overlook those aspects of system performance with a dominant human component where measures would be soldier-rather than hardware-oriented. BLACK HAWK nap-of-the-earth missions and soldier-related reliability problems in all the systems are examples.
- o task and skill analyses and man-machine trade-off studies - there are few instances where this has been done comprehensively and early enough to affect basic system parameters - it was done to a significant extent with the MLRS SPL; it was not done for STINGER or the M1 subsystem
- o MPT requirements estimation - where there is explicit reference to manpower, personnel or training requirements it is often in terms of accepting without examination what has evolved for prior systems; furthermore, such assertions as "no more people should be required to maintain the BLACK HAWK than the Huey" or "M1 maintenance skills should not need to be greater than for the M60"

Table 6

Sources of HMPT Problems in the Systems Studied

- o Mission requirements
- o System description
- o System performance measures and standards
- o Human performance measures and standards
- o Task and skill analyses and man-machine trade-off studies
- o MPT requirements estimation
- o Human factors engineering design
- o Operational system test design and data collection
- o Human performance test design and data collection
- o Test data analysis and reporting
- o Scheduling of HMPT-related events
- o Analysis and decision-making re personnel
- o Training design
- o Concepts associated with HMPT for maintenance

are not expressed in measurable or operational terms; procedures for improving MPT estimates over the course of the WSAP are not systematic. A particular weakness of training requirements is that they do not address all the system tasks.

- o Human factors engineering design - there are a number of contributors to poor HFE: system requirements that discourage trade-off analyses such as the maximum weight of 30 lb. specified for STINGER; system concepts that ignore significant components such as the MLRS fire direction center; non-performance related constraints like the decision to adapt the existing STE for use in M1 fault diagnosis rather than creating new TMDE, etc.
- o Operational system test design and data collection - system testing has been quite controversial and criticisms manifold; perhaps the most significant problems noted in the reverse engineering study were related to incomplete test design and data collection as a result of inadequate guidance and unmeasurable criteria contained in requirements documents and O&O concepts.
- o Human performance test design and data collection - tests are not designed to collect systematically data on human performance as an element of system performance; there are evaluations of skills and training effectiveness as well as human factors engineering; but, except for informal observation, it is difficult to use the data collected to estimate directly the impact of human performance on system performance.
- o Test data analysis and reporting - test data are not comprehensively analyzed and reported, particularly with regard to human performance; examples of the incomplete use of available data include the minimal discussion contained in test reports of the soldier errors that were eliminated by RAM scoring conferences from reliability calculations and the soldier errors that were "zeroed out" prior to MLRS live firings.
- o Scheduling of HMPT-related events - HMPT considerations do not seem to have an impact on scheduling decisions regarding system development - ILS was postponed on M1 and BLACK HAWK for financial reasons; MLRS OT III proceeded without adequate software to demonstrate battery and platoon level man-machine performance, etc.
- o Analysis and decision making re personnel - personnel appear to be specified for new systems largely on an historical basis - certain MOS's and personnel cutoff scores used with preceding systems are more or less automatically adopted for new systems; one result is lack of apparent reasonableness when comparing soldier mental

capabilities across systems - it is not clear (or tested) for example, that SPLL crew need to be of higher mental capability than STINGER gunners.

- o Training design - training designs suffer from omissions associated with incomplete system description; this is particularly true for training devices; training device development also suffers from management complications as with M1 and BLACK HAWK and the unvalidated belief held strongly (e.g., in armor and artillery tradition) that training is better done with actual equipment than with training devices.
- o Concepts associated with HMPT for maintenance - traditional views regarding use of actual equipment for training rather than simulators were just mentioned; other unresolved conceptual problems include the extent to which maintenance should be based on rote procedures and the universality of standard maintenance approaches, e.g., the four-tier approach to organizing maintenance; there are also measurement issues pertaining to such matters as the design of valid, useful, and measurable RAM parameters and the assessment of RAM on the basis of machine, man-machine or total system performance (e.g., MLRS SPLL availability measures refer to the condition of the SPLL hardware not whether the SPLL is "available" with rockets to engage a target).

#### Basic Issues for the WSAP

The lengthy, albeit partial, list of direct contributors to HMPT problems represents rather specific difficulties with the WSAP. Examination of the list leads to several general conclusions.

- o In accord with long-held beliefs, HMPT activities and problems, pertinent to the WSAP extend throughout the acquisition cycle but are most prevalent during the demonstration and validation phase. This is suggested by Figure 9 which shows the specific sources of HMPT problems arrayed against the elements of the system development process and the WSAP phases.

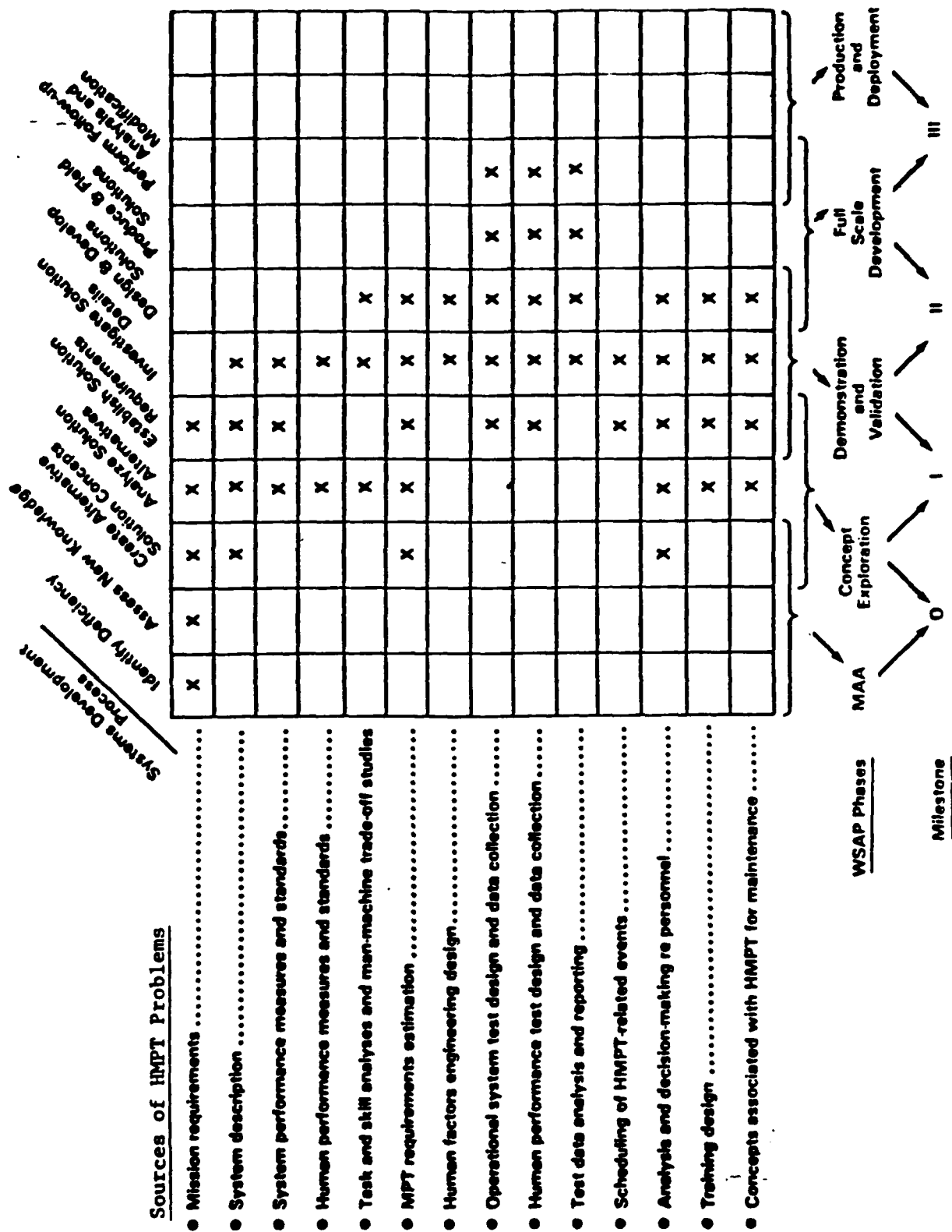


Figure 9. Sources of HMPT problems and their relation to both the system development process and the WSAP phases.

- o Not all the listed contributors to HMPT problems seem directly related to HMPT. Proper definition of mission requirements, system description, etc. are essential if a system is to be fielded without significant HMPT problems. However, these are prerequisite for all aspects of system design. Successful conduct of these activities may not require direct consideration of HMPT issues.
- o A core problem underlies the various factors related to HMPT problems. This is shown schematically in Figure 10. HMPT problems have their origin in inadequate or incomplete analysis of the proposed system during the concept stage. This leads both to incomplete specification of requirements and inappropriate assumptions regarding system features. HMPT design parameters and field test design become too narrowly defined. The incomplete field tests cannot identify comprehensively errors of commission and omission regarding HMPT. The end results are: (1) HMPT problems; and (2) uncertainty regarding the adequacy of system performance along with inconclusive evidence concerning the importance of HMPT problems.

#### V. Improving the Weapon System Acquisition Process

##### Basic Change

The nature of the problems just presented points to the need for a fundamental change in perspective regarding weapon systems - a new "institutional set" is required. The current view and the desired view are represented in two of the documents cited earlier:

"While these systems may have the capability to perform their missions, it is often of little value because not all the systems can be adequately operated, maintained, or supported"<sup>1</sup>

"Significant improvement will not occur quickly unless efforts are integrated, the personnel and doctrine people become more actively involved early in the materiel development process, and the Army addresses man/machine interface in its broadest sense and begins to

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<sup>1</sup>Comptroller General of the United States, Effectiveness of U.S. Forces Can Be Decreased through Improved Weapon System Design, Report PSAD-81-17, January 29, 1981

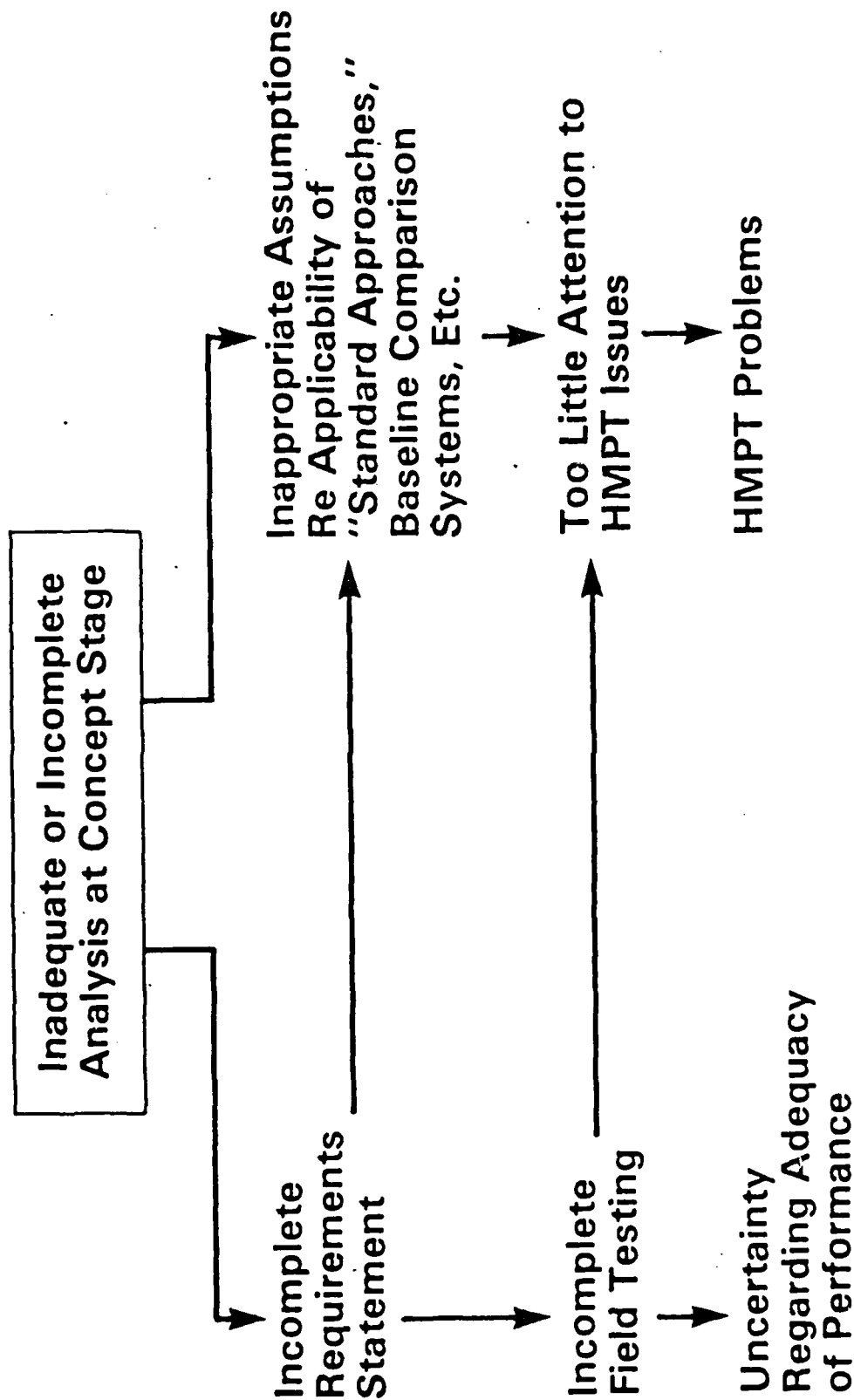


Figure 10. Problems with the Weapon System Acquisition Process.



think tactical system development in lieu of individual materiel development, individual people development and individual support development."<sup>2</sup>

The GAO implicitly defines a weapon system as an entity capable of performing missions but separate from elements that operate, maintain or support it. This perspective is consistent with what was observed in the system studies where the focus of requirements, testing and management decision-making was all on hardware performance - and not even on all hardware in the system but principally the major components providing the technical capability. Such items as mission flexibility kits and TMDE tended to be overlooked. This non-integrated approach to system conceptualization is further illustrated by the way design characteristics and proposal evaluation criteria are specified. Human factors, for example, is typically listed separately from various aspects of system performance as though the former were not an integral part of the latter.

Kerwin and Blanchard, on the other hand, seem to have a more comprehensive view of the concept of a system. They refer to "tactical system development" and contrast it with the separate development of materiel, people and support. The need for the system development community to adopt this concept of a system as the summation of all the elements required to fulfill a mission is prerequisite to the long-term alleviation of HMPT problems.

This kind of institutional change cannot be accomplished instantaneously by fiat. It must be approached by systematic modification of the concepts and procedures associated with all aspects of the WSAP. The remainder of this report addresses recommendations for doing this. In addition, the report itself may prove useful as a resource for a general educational campaign aimed at changing attitudes concerning weapon system concepts.

### Recommendations

Specific recommendations from the Reverse Engineering Project have been developed, tailored to the needs of a variety of special audiences. However, the recommendations can be stated in broad terms. They range from consideration of total system development of which HMPT is an integral part to matters of appropriately experienced staff and the locus of responsibility for system development.

- o Total system performance in the operational environment should be the focus of the WSAP from initial analyses through testing and decision making.

<sup>2</sup>Kerwin, Walter, G.S. Blanchard, E.M. Atzinger and P.E. Topper. Man/Machine Interface - A Growing Crisis, Army Top Problem Areas Discussion Paper No. 2, ANSAA, August 1980.

- o Past practices (e.g., involving baseline comparison systems or "standard" procedures) should not be adopted for new, or successor, systems without specific analysis of their applicability.
- o Actions and documents in the WSAP should not be approved until their comprehensiveness including attention to HMPT has been verified.
- o There should be systematic monitoring of processes specified in requirements documents (e.g., trade-off studies) and planning documents.
- o WSAP decision making bearing on HMPT issues should reflect estimates of the cost-effectiveness and cost-benefits associated with the available options (with respect, for example, to funding and scheduling of the WSAP).
- o Characteristics of the acquisition (e.g., competition, degree of multiple proponentcy, accelerated development) and their impact on HMPT should be explicitly considered in WSAP planning.
- o Actions should be taken to reduce turnover and improve HMPT-related training of appropriate personnel in DARCOM, TRADOC, OTEA and other agencies.
- o In selecting and monitoring contractors, the competence of their staff in terms of HMPT should be assured.
- o Responsibility for development of the total system including HMPT should be centralized to the maximum extent possible.

#### A Final Statement

The key general recommendation is the last one listed: that responsibility for development of a total system including HMPT should be centralized to the maximum extent possible. Currently primary responsibility rests with different offices at varying intervals in the acquisition process, e.g., the TRADOC Systems Manager (TSM) during the earlier conceptual phases and the DARCOM Project Manager (PM) later in the cycle. Complete authority can never rest with any single office because of the multiplicity of ways in which a new system must be integrated into the force structure. However, much more can be done to focus and demarcate responsibility for clearly defined phases of the system development.

In particular, the role of the PM should be enhanced for a major portion of the developmental cycle. Of all the individuals involved in the WSAP, the PM has by far the best understanding and the most resources for developing systems. Furthermore, the materiel developer cannot properly do his job unless he considers hardware, software and people simultaneously. Thus, the approach that takes maximum advantage of current processes and promises the least disruption is to augment the role of the PM for total systems responsibility including HMPT.

Several things need to be done to accomplish this including:

- o There should be a transition plan prepared and agreed to by TRADOC and DARCOM that describes the conditions under which responsibility is transferred from the former to the latter at project initiation.
- o The PM's Charter should include an assignment of responsibility for the total system development.
- o HMPT issues are important and complex. The PM's staff should include individuals with the capability to undertake various activities related to HMPT including contract monitoring.
- o Generic requirements documents should be developed to be used as guidance for describing the system including HMPT components for which the PM will be responsible. (Recommendations for the ROC have been prepared by ARI).
- o RFP and contract boilerplate addressing HMPT issues should be developed to ensure that contractors' responsibilities are clearly understood. (Recommended language has been prepared by ARI).

Most importantly, the PM should be required to adopt the total system concept and be judged accordingly.